CLAIMS

1. A method for measuring the electrical impedance of sections of a living body, comprising:
   a) providing a plurality of electrodes each of which is disposed on a section of said living body, where said electrodes are capable of applying an electrical current through at least one probed section, and measure the electrical voltage over said sections, of said living body;
   b) providing an apparatus capable of measuring the voltages over said sections and accurately calculating the impedance ($Z(t)$), the changes ($\Delta Z(t)$) in said impedance, the resistance $R(t)$, and the changes ($\Delta R(t)$) in said resistance, of at least said probed section, by considering the electrical current distortion components resulting from the electrical currents flowing in the other sections which are not probed, utilizing an electrical model based on the distribution of the electrical currents through said sections, by repeatedly performing the following steps:
      b.1) applying an electrical current through said probed section of the living body via a pair of electrodes, and measuring the electrical voltage over said probed section and over the other sections;
      b.2) applying an electrical current through one or more of said other sections and at each instance measuring the electrical voltage over said other sections; and
      b.3) calculating said impedance and resistance and said changes utilizing said measurements and said applied currents, according to said electrical model.

2. A method according to claim 1, wherein at least one of the sections is associated with an inner body organ.

3. A method according to claim 1, wherein the electrodes are applied as follows:

a) applying at least four electrodes to the upper and lower limbs of said body, such that at least one of said electrodes is applied to the right arm, to the left arm, to the right leg, and to the left leg; and

b) applying at least four electrodes to the trunk area of the measured body, such that at least one of said electrodes is applied to the upper part of the right side of the trunk, to the lower part of the right side of the trunk, to the upper part of left side of the trunk, and to the lower part of the left side of the trunk.

4. A method for measuring the electrical impedance of sections of a living body utilizing an electrical model based on the distribution of electrical currents through said sections comprising:

a) providing a plurality of electrodes each of which is disposed on said sections of said living body, where said electrodes are capable of applying an electrical current through at least one section, and measure the electrical voltage over other sections, of said living body;

b) providing processing means capable of selecting one or more pairs of electrodes to be used as excitation electrodes and one or more pairs of electrodes to be used as sensing electrodes, capable of outputting and inputting digital signals and of processing said signals;

c) providing a digital-to-analog converter capable of receiving digital signals from said processing means and outputting a corresponding analog signal;

d) providing a current source capable of producing an electrical current, the magnitude of which is proportional to the amplitude of said analog signal;

e) providing an amplifier for amplifying the signal obtained via said sensing electrodes;

f) providing a switching circuitry linked to said processing means and to said current source and said amplifier, and capable of applying said electrical current to said pair of excitation electrodes, and pick up an electrical voltage measurement via said sensing electrodes;

g) providing an analog-to-digital converter for converting the amplified signal and delivering a corresponding digital signal to said processing means; and

wherein said electrical current is applied through said at least one section via the selected pair of excitation electrodes, and at each instance the electrical voltage over the selected sensing electrodes is measured, and where said electrical impedance is calculated by said processing means utilizing the measured electrical voltages and said applied currents, according to said electrical model.

5. A method according to claim 4, wherein at least one of the sections is associated with an inner body organ.

6. A method according to claim 4, further comprising providing a low-pass-filter for filtering the signal used as a reference for producing the electrical current.

7. A method according to claim 4, further comprising providing a high-pass-filter for filtering the analog signal to be converted by the analog-to-digital converter.

8. A method according to claim 4, further comprising a programmable gain amplifier controlled by the processing means for amplifying the amplitude of the analog signal to be converted by the analog-to-digital converter.

9. A method according to claims 7 and 8, wherein the analog signal to be converted by the analog-to-digital converter is filtered by the high-pass-filter and amplified the programmable gain amplifier.

10. A method according to claim 7, 8, or 9, further comprising processing the digital signal produced by the analog-to-digital converter and computing the

active component of the impedance and the changes of said component, by performing the following steps:

a) splitting said digital signal into wave-packets, where each wave-packet includes a complete number cycles of said signal;
b) multiplying said wave-packets by a digital sinusoidal waveform with the same frequency and phase as the signal cycles in the wave-packets;
c) summing the results of the multiplication of a wave-packet by said digital sinusoidal waveform;
d) storing the summation results in a memory;
e) calculating the measured resistance by utilizing said summation results and the electrical model;
f) filtering said measured resistance by a low-pass-filter to obtain the mean value of the said measured resistance; and
g) subtracting said mean value from said measured resistance to obtain the changes of said measured resistance and basal resistance.

11. A method according to claim 10, wherein the multiplication of the wave-packets comprises multiplying each wave-packet signal by itself, thereby raising it to the second power, to obtain the impedance value and it changes.

12. A method for measuring the electrical impedance of sections of a living body utilizing an electrical model based on the distribution of electrical currents through said sections, comprising:

a) applying at least four electrodes to the upper and lower limbs of the measured body, such that at least one of said electrodes is applied to the right arm, to the left arm, to the right leg, and to the left leg;
b) applying at least four electrodes to the trunk area of the measured body, such that at least one of said electrodes is applied to the upper part of the right side of the trunk, to the lower part of the right side of the trunk, to the upper part of left side of the trunk, and to the lower part of the left side of the trunk;

c) performing at least six of the following measurements:

c.1) measuring the voltage over a right pair of electrodes applied to the upper and lower parts of the right side of the trunk, and the voltage over a left pair of electrodes applied to the upper and lower parts of the left side of the trunk, where said voltages are measured in response to a first excitation current applied via electrodes applied to the left leg and to the left arm;

c.2) measuring the voltage over said right pair of electrodes, and the voltage over said left pair of electrodes, where said voltages are measured in response to a second excitation current applied via electrodes applied to the right leg and to the right arm;

c.3) measuring the voltage over an upper pair of electrodes applied to the right and to the left sides of the upper part of the of the trunk, and the voltage over a lower pair of electrodes applied to the right and to the left sides of the lower part of the trunk, said voltages are measured in response to a third excitation current applied via electrodes applied to the right leg and to the left leg;

c.4) measuring the voltage over said upper pair of electrodes, and over said lower pair of electrodes, said voltages are measured in response to a fourth excitation current applied via electrodes applied to the right arm and to the left arm; and

d) computing the electrical impedance between said pairs of electrodes utilizing the measured voltages by said at least six measurements according to said electrical model.

13. A method according to claim 12, wherein the at least four electrodes applied to the upper and lower limbs are applied to the extremities of said limbs.

14. A method according to claim 12, wherein the at least four electrodes applied to the trunk area are applied to the upper and lower parts of left and right sides of the chest.

15. A method according to claim 12, further comprising providing an electrode applied to the upper head section for measuring peripheral blood flow parameters utilizing a bipolar electrode configuration.

16. A method according to claim 12, in which an electrode is applied to the upper head section, instead of the electrodes applied to the upper limbs, of the measured body.

17. A method according to claim 15 or 16, further comprising providing an additional electrode applied to the upper head section in the vicinity of the electrode for measuring peripheral blood flow parameters utilizing a tetrapolar electrode configuration.

18. A method according to claim 12, further comprising applying at least four additional electrodes, each of which is applied to one of the upper or lower limbs and placed in the vicinity of an excitation electrode, for measuring peripheral blood flow parameters utilizing a tetrapolar electrode configuration.

19. A method according to claim 12, wherein only the active component of the impedance is computed.

20. A method according to claim 12, wherein electrical impedances associated with the aortic flow, pulmonary arterial flow, and pulmonary flow parameters, are obtained by carrying out the following measurements:

a) measuring the voltage obtained via a right pair of electrodes applied to the upper and lower parts of the right side of the trunk, *U1*, and the voltage obtained via a left pair of electrodes applied to the upper and lower parts of the left side of the trunk, *U12,* in response to an excitation current *Is* applied through electrodes applied to the left arm and to the left leg;

b) measuring the voltage obtained via a left pair of electrodes applied to the upper and lower parts of the left trunk, *U2*, and the voltage obtained via a right pair of electrodes applied to the upper and lower parts of the right trunk, *U21*, in response to an excitation current *Is* applied through electrodes applied to the right arm and to the right leg;

c) measuring the voltage obtained by an upper pair of electrodes applied to the right and left parts of the upper trunk, *U3*, and by a lower pair of electrodes applied to the right and left parts of the lower trunk, *U34*, in response to an excitation current *Is* applied through electrodes applied to the right leg and to the left leg, and

computing the impedance signals:

- $R1=(U1*U2-U12*U21)/(Is*(U2-U12))$ between said right pair of sensing electrodes,
- $R2=(U1*U2-U12*U21)/(Is*(U1-U21))$ between said left pair of sensing electrodes,
- $R3=U3*(R1+R2)/(Is*(R1+R2)-U3+U34))$ between said upper pair of sensing electrodes, and
- $R4= (U34*(R1+R2))/(U3-U34)$ between said lower pair of sensing electrodes.

21. A method according to claim 12, further comprising measuring electrical impedances associated with parameters of the peripheral blood flow as follows:

a) obtaining the electrical impedance associated with the right arm by measuring the voltage obtained via an electrode applied to said arm and an electrode applied to the upper part of the right side of the trunk, where said voltage is being responsive to an excitation current applied via said electrodes;

b) obtaining the electrical impedance associated with blood flow parameters of the left arm by measuring the voltage obtained via an electrode applied to said arm and an electrode applied to the upper part of the left side of the

trunk, where said voltage is being responsive to an excitation current applied via said electrodes;

c) obtaining the electrical impedance associated with blood flow parameters of the right leg by measuring the voltage obtained via an electrode applied to said leg and an electrode applied to the lower part of the right side of the trunk, where said voltage is being responsive to an excitation current applied via said electrodes; and

d) obtaining the electrical impedance associated with flow parameters of the left leg by measuring the voltage obtained via an electrode applied to said leg and an electrode applied to the lower part of the left trunk, where said voltage is being responsive to an excitation current applied via said electrodes.

22. A method according to claim 12, further comprising providing an additional pair of electrodes applied to one of the fingers of the measured body for measuring the electrical impedance associated the parameters of the peripheral blood flow, utilizing a bipolar electrode configuration.

23. A method according to claim 12, wherein the at least six measurements are performed by carrying out the following steps:

a) selecting a pair of electrodes from the at least four electrodes applied to the upper and lower limbs to be used as excitation electrodes and a pair of electrodes from the at least four electrodes applied to the trunk area to be used as sensing electrodes;

b) continuously generating digital signal corresponding to a sinusoidal signal;

c) converting said digital signal into an analog signal;

d) applying a constant electrical current, the magnitude of which is proportional to the magnitude of said analog signal, via said excitation electrodes;

e) amplifying the voltage over said sensing electrodes; and

f) converting said amplified voltage into a digital signal;

wherein said digital signal is used for the computation of the impedance signal.

24. A method according to claim 23, further comprising processing the amplified voltage converted into a digital signal and computing the active component of the impedance and the changes of said component, by performing the following steps:
    a) splitting said digital signal into wave-packets, where each wave-packet includes a complete number cycles of said signal;
    b) multiplying said wave-packets by a digital sinusoidal waveform with the same frequency and phase as the signal cycles in the wave-packets;
    c) summing the results of the multiplication of a wave-packet by said digital sinusoidal waveform;
    d) storing the summation results in a memory;
    e) calculating the measured resistance by utilizing said summation results and the electrical model;
    f) filtering said measured resistance by a low-pass-filter to obtain the mean value of said measured resistance; and
    g) subtracting said mean value from said measured resistance to obtain the changes of said measured resistance and basal resistance.

25. A method according to claim 23, wherein the multiplication of the wave-packet comprises multiplying each wave-packets signal by itself, thereby raising it to the second power, to obtain the impedance value and it changes.

26. A method according to claim 23, further comprising filtering the analog signal by a low-pass-filter.

27. A method according to claim 23, further comprising filtering the amplified signal by a high-pass-filter.

28. A method according to claims 1, 4, or 12, further comprising providing means for measuring ECG signals via at least three electrodes.

29. A method according to claims 1, 4, or 12, wherein the electrical current is an alternating electrical current.

30. A method according to claims 1, 4, or 12, wherein the electrical current is produced by a high stability current source.

31. A method according to claims 1, 4, or 12, wherein impedance measurements are used for accurately assessing pulmonary systematic and peripheral blood flow and calculating hemodynamic parameters of the probed sections.

32. A system for measuring the electrical impedance of sections of a living body utilizing an electrical model based on the distribution of electrical currents through said sections comprising:
   a) a plurality of electrodes each of which is disposed on sections of said living body, where said electrodes are capable of applying an electrical current through at least one section, and measure the electrical voltage over other sections, of said living body;
   b) a processing means capable of selecting one or more pairs of electrodes to be used as excitation electrodes and one or more pairs of electrodes to be used as sensing electrodes, capable of outputting and inputting digital signals and of processing said signals;
   c) a digital-to-analog converter capable of receiving digital signals from said processing means and outputting a corresponding analog signal to be used as a reference for producing a proportional electrical current;
   d) a current source capable of producing an electrical current, the magnitude of which is proportional to the amplitude of said analog signal;
   e) a switching circuitry linked to said processing means and to said current source, and capable of applying said electrical current to said pair of excitation electrodes, and pick up an electrical voltage measurement via said sensing electrodes;

f) an amplifier for obtaining the signal obtained via said sensing electrodes and amplifying it;

g) an analog-to-digital converter for converting the amplified signal and delivering a corresponding digital signal to said processing means; and

wherein said electrical current is applied through said at least one section via the selected pair of excitation electrodes, and at each instance the electrical voltage over the selected sensing electrodes is measured, and where said electrical impedance is calculated by said processing means utilizing the measured electrical voltages and said applied currents, according to said electrical model.

33. A system according to claim 32, wherein at least one of the sections is associated with and inner body organ.

34. A system according to claim 32, further comprising a low-pass-filter for filtering the signal used as a reference for producing the electrical current.

35. A system according to claim 32, further comprising a high-pass-filter for filtering the analog signal to be converted by the analog-to-digital converter.

36. A system according to claim 32, further comprising a programmable gain amplifier controlled by the processing means for amplifying the amplitude of the analog signal to be converted by the analog-to-digital converter.

37. A system according to claims 35 and 36, wherein the analog signal to be converted by the analog-to-digital converter is filtered by the high-pass-filter and amplified the programmable gain amplifier.

38. A system according to claim 35, 36, or 37, wherein the processing means comprises:

a) a splitter for splitting said digital signal into wave-packets, where each wave-packet includes a complete number cycles of said signal;

b) a sine wave generator for generating a sinusoidal waveform of the same frequency as of said digital signal;

c) a phase shift module capable of determining phase shifts between said digital signal and said sinusoidal waveform and eliminating them;

d) a multiplier for multiplying the wave-packet signals received on it first input by a digital signal received on it second input, where said signals are of the same frequency, phase, and cycles;

e) a switching circuitry for selecting the signal on said second input to be said wave-packet signals or said sinusoidal waveform;

f) a summator for summing the multiplication results of each wave-packet;

g) a memory for storing said summation results;

h) a low-pass-filter for filtering computed resistances or impedances values to obtain the mean value of said computed values; and

i) a subtractor for subtracting said mean value from said computed values to obtain the changes of said computed values;

wherein the state of said switching means is determined by the processing means according to the required measurement, and wherein the summation results stored in said memory are used by said processing means for computing the resistances or impedances values according to the electrical model used.

39. A system according to claim 32, wherein at least four electrodes are applied to the upper and lower limbs of the measured body, such that at least one of said electrodes is applied to the right arm, to the left arm, to the right leg, and to the left leg.

40. A system according to claim 32, wherein at least four electrodes are applied to the trunk area of the measured body, such that at least one of said electrodes is applied to the upper part of the right side of the trunk, to the lower part of the right side of the trunk, to the upper part of left side of the trunk, and to the lower part of the left side of the trunk.

41. A system according to claims 39 and 40, wherein at least six of the following measurements are performed:
    a) measurement in which the voltage over a right pair of electrodes applied to the upper and lower parts of the right side of the trunk is measured, and the voltage over a left pair of electrodes applied to the upper and lower parts of the left side of the trunk is measured, where said voltages are measured in response to a first excitation current applied via electrodes applied to the left leg and to the left arm;
    b) measurement in which the voltage over said right pair of electrodes is measured, and the voltage over said left pair of electrodes is measured, where said voltages are measured in response to a second excitation current applied via electrodes applied to the right leg and to the right arm;
    c) measurement in which the voltage over an upper pair of electrodes applied to the right and to the left sides of the upper part of the of the trunk is measured, and the voltage over a lower pair of electrodes applied to the right and to the left sides of the lower part of the trunk is measured, said voltages are measured in response to a third excitation current applied via electrodes applied to the right leg and to the left leg; and
    d) measurement in which the voltage over said upper pair of electrodes is measured, and the voltage over said lower pair of electrodes is measured, said voltages are measured in response to a fourth excitation current applied via electrodes applied to the right arm and to the left arm.

42. A system according to claim 39, wherein the at least four electrodes applied to the upper and lower limbs are applied to the extremities of said limbs.

43. A system according to claim 40, wherein the at least four electrodes applied to the trunk area are applied to upper and lower parts of left and right sides of the chest.

44. A system according to claim 39, further comprising an electrode applied to the upper head section for measuring peripheral blood flow parameters utilizing a bipolar electrode configuration.

45. A system according to claim 39, in which an electrode in applied to the upper head section, instead of the electrodes applied to the upper limbs, of the measured body.

46. A method according to claim 42 or 43, further comprising an additional electrode applied to the upper head section in the vicinity of the electrode, for measuring peripheral blood flow parameters utilizing a tetrapolar electrode configuration.

47. A system according to claim 39, further comprising applying at least four additional electrodes, each of which is applied to one of the upper or lower limbs and placed in the vicinity of an excitation electrode, for measuring peripheral blood flow parameters utilizing a tetrapolar electrode configuration.

48. A system according to claim 39, wherein only the active component of the impedance is computed.

49. A system according to claim 39 and 40, wherein electrical impedances associated with the aortic flow, pulmonary arterial flow, and pulmonary flow parameters, are obtained by carrying out the following measurements and computations:

a) a measurement of the voltage obtained via a right pair of electrodes applied to the upper and lower parts of the right side of the trunk, *U1*, and of the voltage obtained via a left pair of electrodes applied to the upper and lower parts of the left side of the trunk, *U12,* in response to an excitation

current *Is* applied through electrodes applied to the left arm and to the left leg;

b) a measurement of the voltage obtained via a left pair of electrodes applied to the upper and lower parts of the left trunk, U2, and the voltage obtained via a right pair of electrodes applied to the upper and lower parts of the right trunk, U21, in response to an excitation current applied through electrodes applied to the right arm and to the right leg;

c) a measurement of the voltage obtained by an upper pair of electrodes applied to the right and left parts of the upper trunk, U3, and by a lower pair of electrodes applied to the right and left parts of the lower trunk, U34, in response to an excitation current applied through electrodes applied to the right leg and to the left leg; and

d) a computation of the following impedance signals:

- $R1=(U1*U2-U12*U21)/(Is*(U2-U12))$ between said right pair of sensing electrodes,
- $R2=(U1*U2-U12*U21)/(Is*(U1-U21))$ between said left pair of sensing electrodes,
- $R3=U3*(R1+R2)/(Is*(R1+R2)-U3+U34))$ between said upper pair of sensing electrodes, and
- $R4= (U34*(R1+R2))/(U3-U34)$ between said lower pair of sensing electrodes.

50. A system according to claim 39 and 40, further comprising measuring electrical impedances associated with parameters of the peripheral blood flow utilizing a bipolar electrode configuration.

51. A system according to claim 39, further comprising an additional pair of electrodes applied to one of the fingers of the measured body for measuring the electrical impedance associated the parameters of the peripheral blood flow, utilizing a bipolar electrode configuration.

52. A system according to claim 51, further comprising an additional pair of electrodes applied the finger of the measured body for measuring the electrical impedance associated the parameters of the peripheral blood flow, utilizing a tetrapolar electrode configuration.

53. A system according to claim 32, further comprising providing means for measuring ECG signals via at least three electrodes.

54. A system according to claim 32, wherein the electrical current is an alternating electrical current.

55. A system according to claim 32, wherein impedance measurements are used for accurately assessing pulmonary systematic and peripheral blood flow and calculating hemodynamic parameters of the probed sections.

56. A system according to claim 32, wherein the resistance R for assessment of peripheral blood flow parameters is computed utilizing the excitation current Is and the measured voltage Ua, as follows: $R=Ua/Is$.

57. A system according to claims 32 and 53, wherein the measuring of the ECG signals and of the electrical voltages and the computing of the impedance and its changes are performed utilizing a sample rate of at least 200 sample/sec.